ADVANCED OXIDE MATERIAL SYSTEMS FOR 1650°C THERMAL/ENVIRONMENTAL BARRIER COATING APPLICATIONS

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Abstract

Advanced thermal/environmental barrier coatings (T/EBCs) are being developed for low emission SiC/SiC ceramic matrix composite (CMC) combustor and vane applications to extend the CMC liner and vane temperature capability to 1650°C (3000°F) in oxidizing and water-vapor containing combustion environments. The 1650°C T/EBC system is required to have better thermal stability, lower thermal conductivity, and improved sintering and thermal stress resistance than current coating systems.

In this paper, the thermal conductivity, water vapor stability and cyclic durability of selected candidate zirconia-/hafnia-, pyrochlore- and magnetoplumbite-based T/EBC materials are evaluated. The test results have been used to downselect the T/EBC coating materials, and help demonstrate advanced 1650°C coatings feasibility with long-term cyclic durability.

Objectives

— **Thermal conductivity and sintering behavior of advanced oxide coating materials**

Zirconia-/hafnia-, pyrochlore- and magnetoplumbite-based T/EBC materials studied

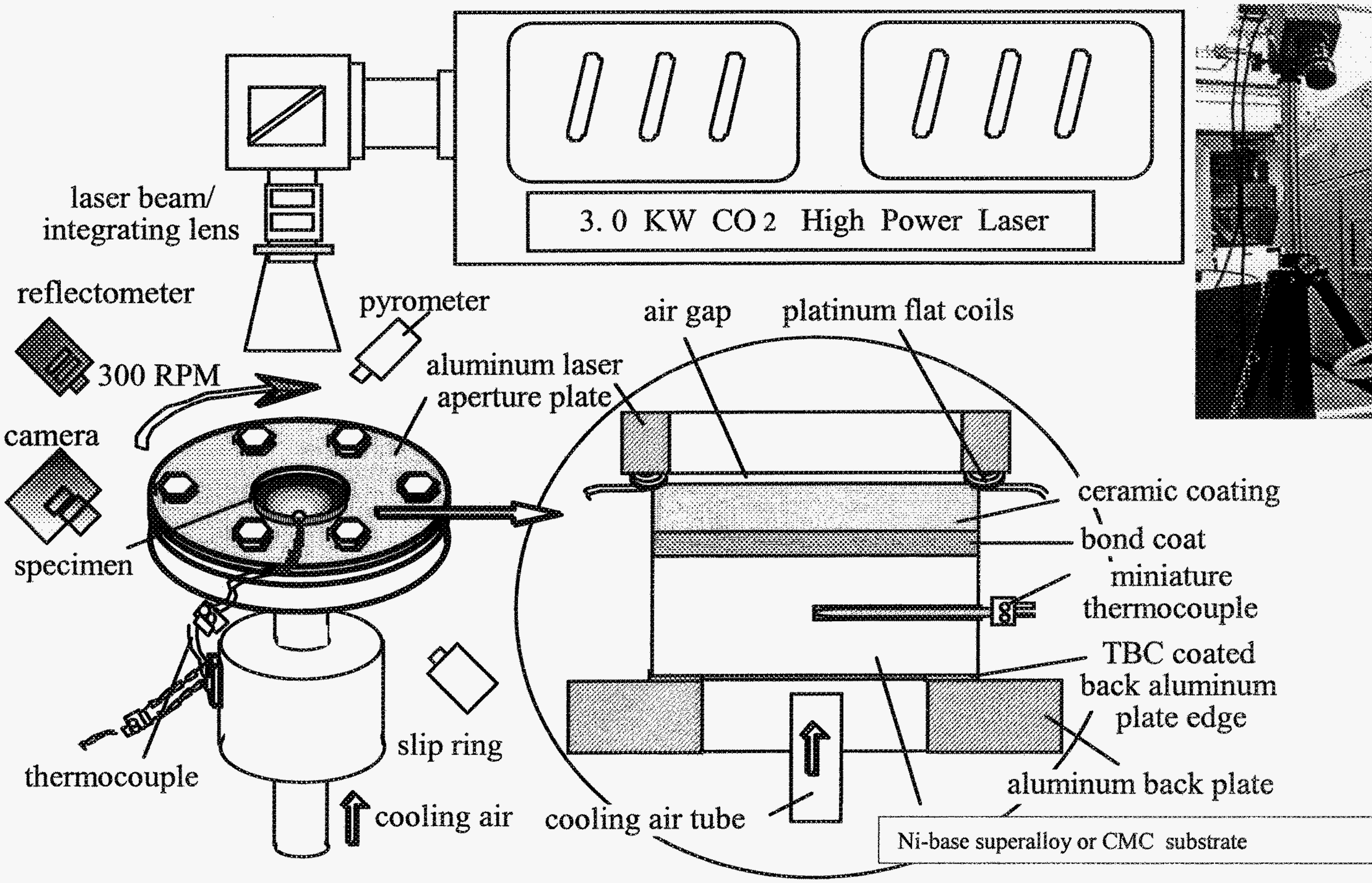
Hot-pressed specimens and plasma-sprayed coatings investigated

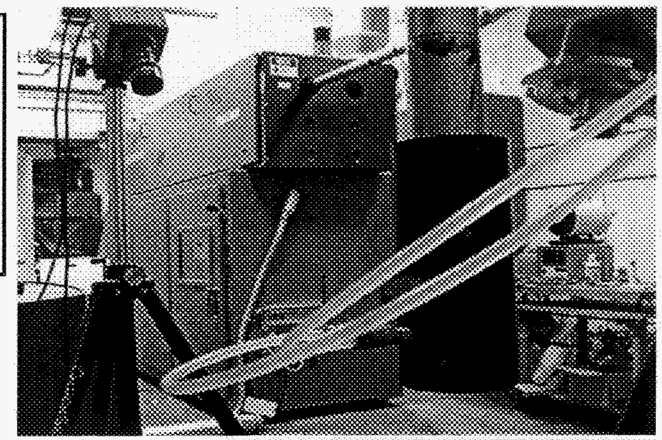
— **Water vapor stability of the advanced oxides at temperatures of 1650°C (3000°F)**

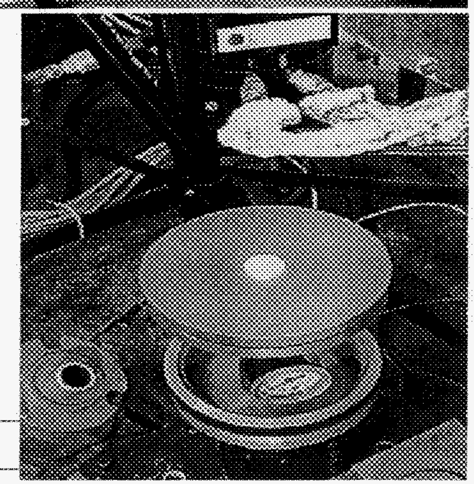
— **HfO_2-Y_2O_3 coating system 1650°C (3000°F) cyclic durability**

A Laser Heat-Flux Approach for Ceramic Coating Thermal Conductivity Measurements

- A uniform laser (wavelength 10.6 μm) power distribution achieved using integrating lens combined with lens/specimen rotation
- The ceramic surface and substrate temperatures measured by pyrometers and/or by an embedded miniature thermocouple
- Thermal conductivity measured at 5 second intervals in real time

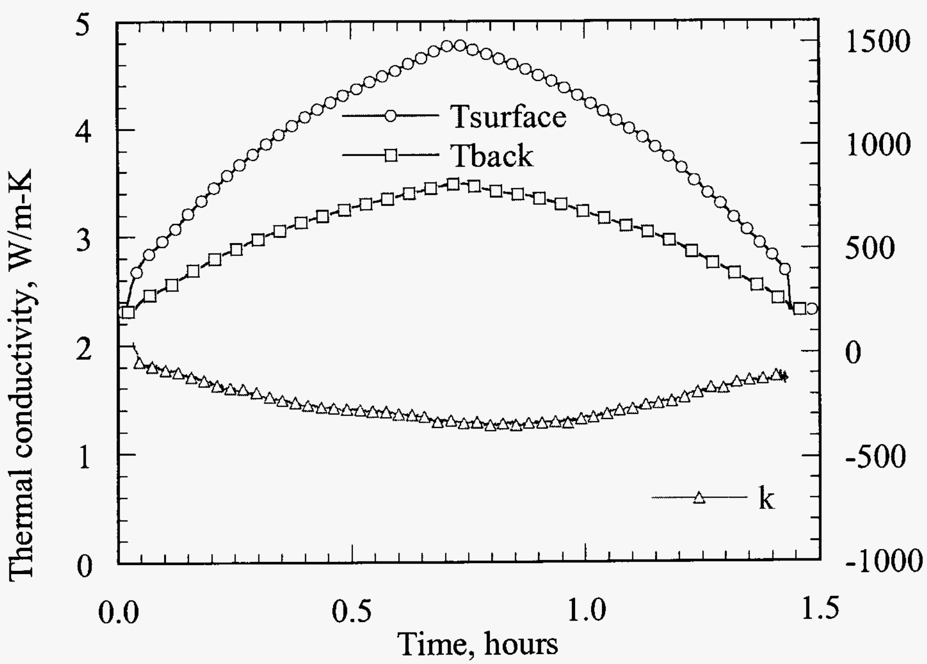


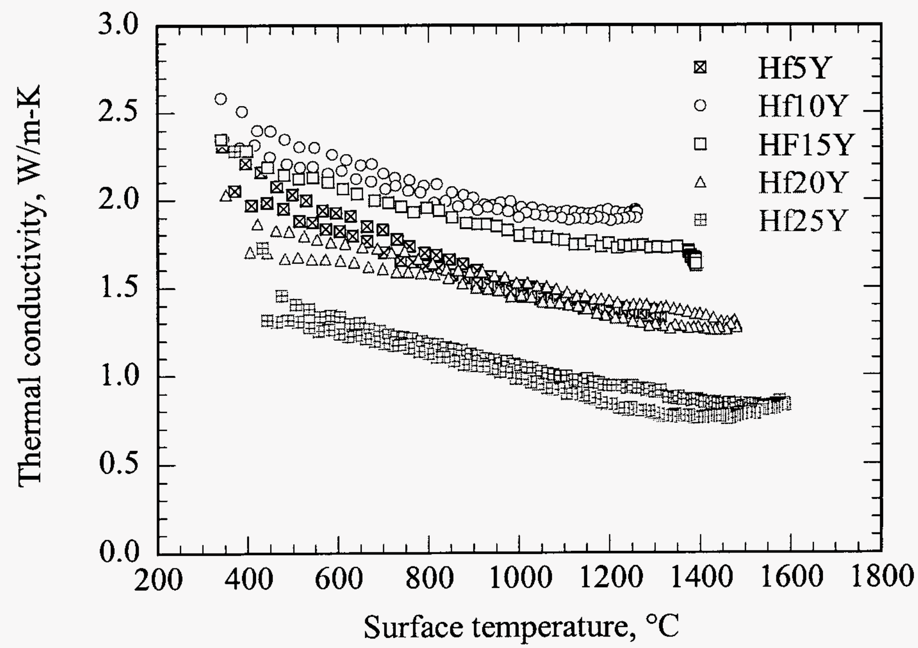




Thermal Conductivity Measurements of Hot-Pressed HfO_2-Y_2O_3 Coatings

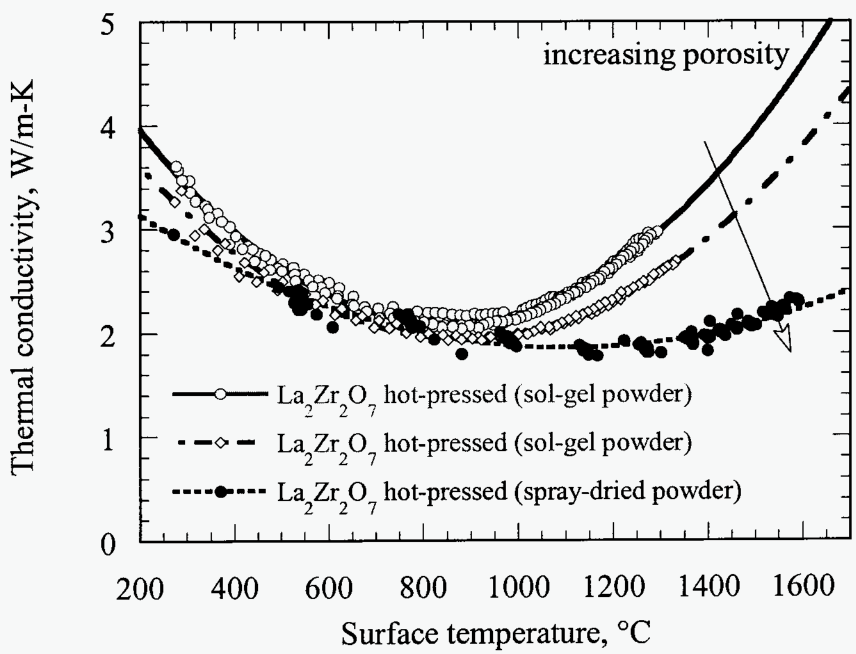
— **Temperature dependence can be determined using the laser heat-flux test approach**

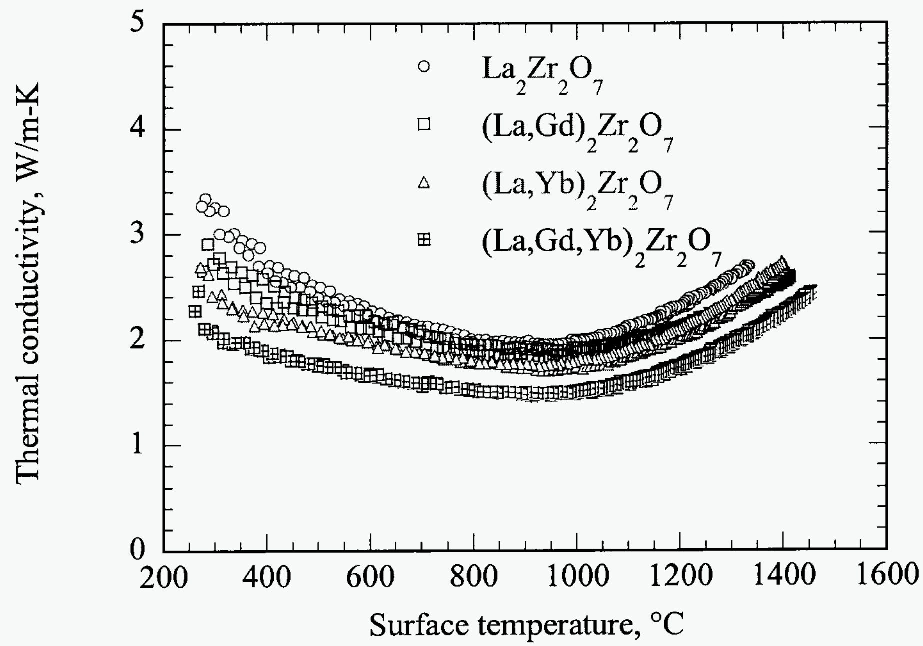




Thermal Conductivity of Hot-Pressed Pyrochlore Oxides

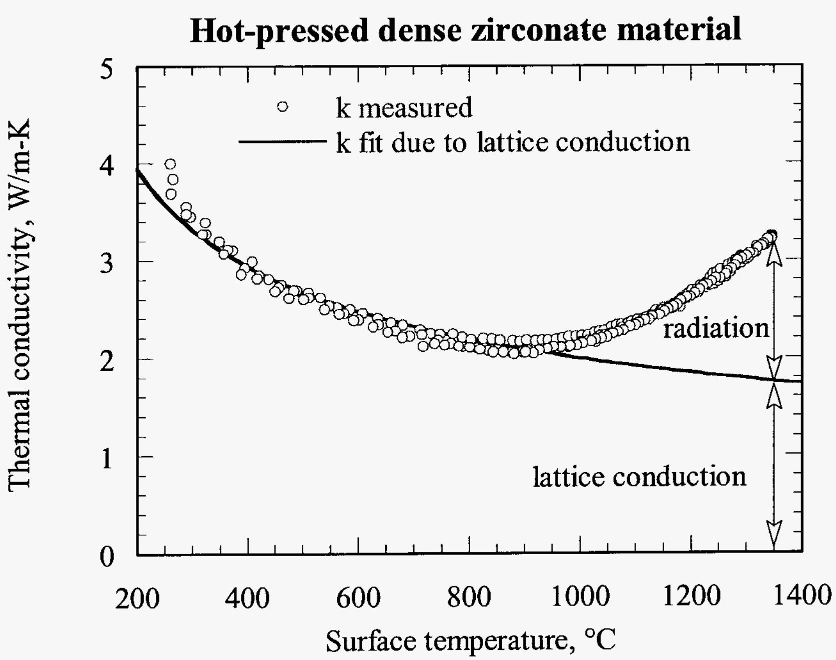
- **Thermal conductivity can increase by more than 100% at high temperature due to the increased radiation heat-transfer under thermal gradient conditions**
- **The multiple rare earth oxide co-doped pyrochlore oxides showed lower conductivity as compared to the undoped $La_2Zr_2O_7$**

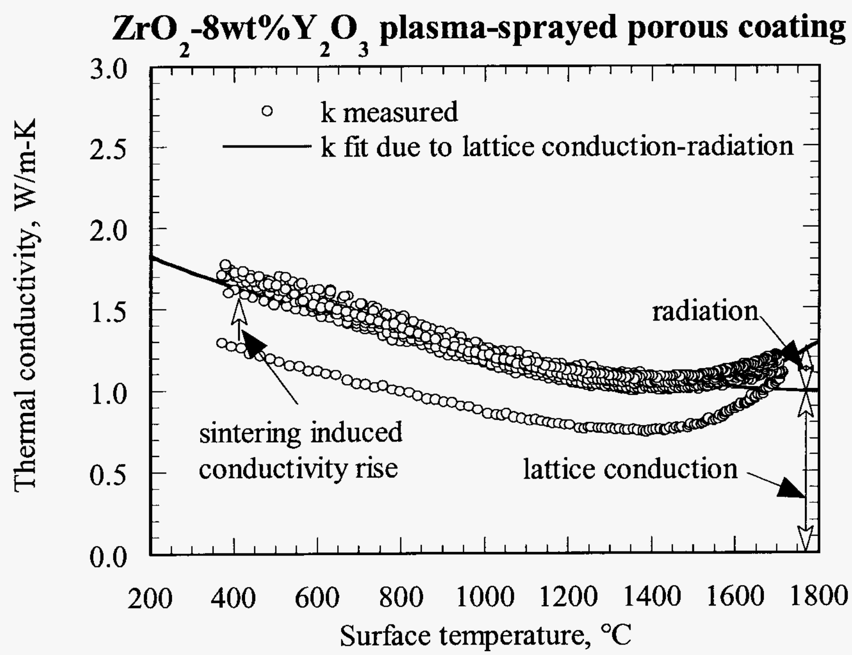




Thermal Conductivity of Hot-Pressed Pyrochlore Oxide and Plasma-Sprayed Coating Specimens

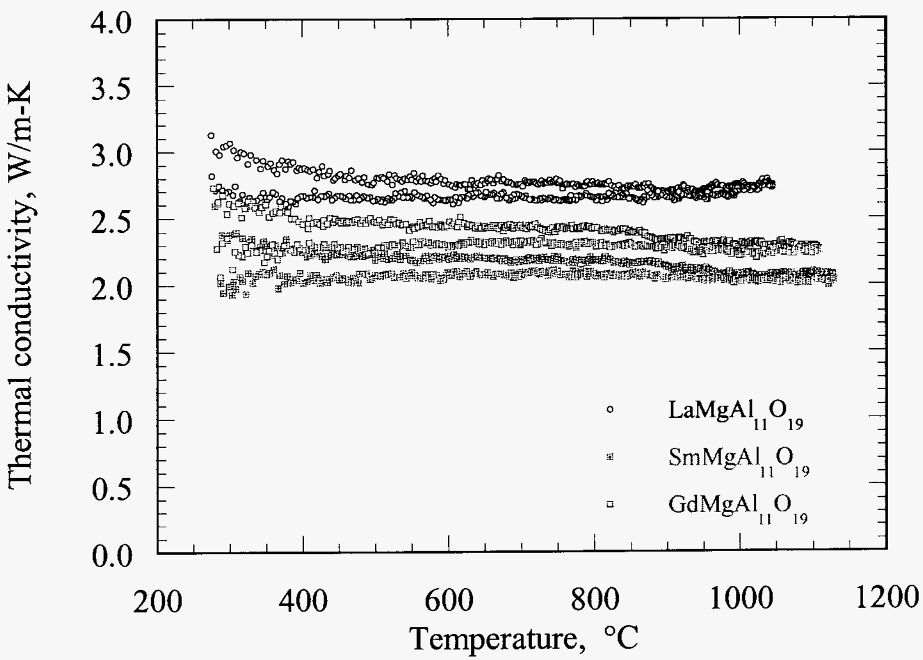
— **Plasma-sprayed coatings showed significantly lower radiation conductivity due to the increased scattering and reflectivity of micro-porosity**

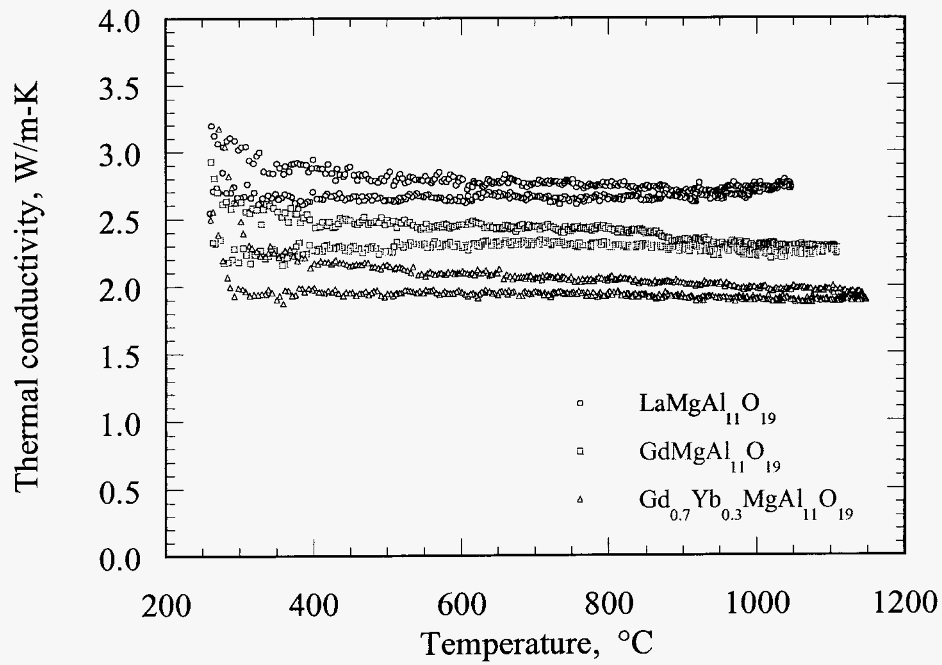




Thermal Conductivity of Magnetoplumbites

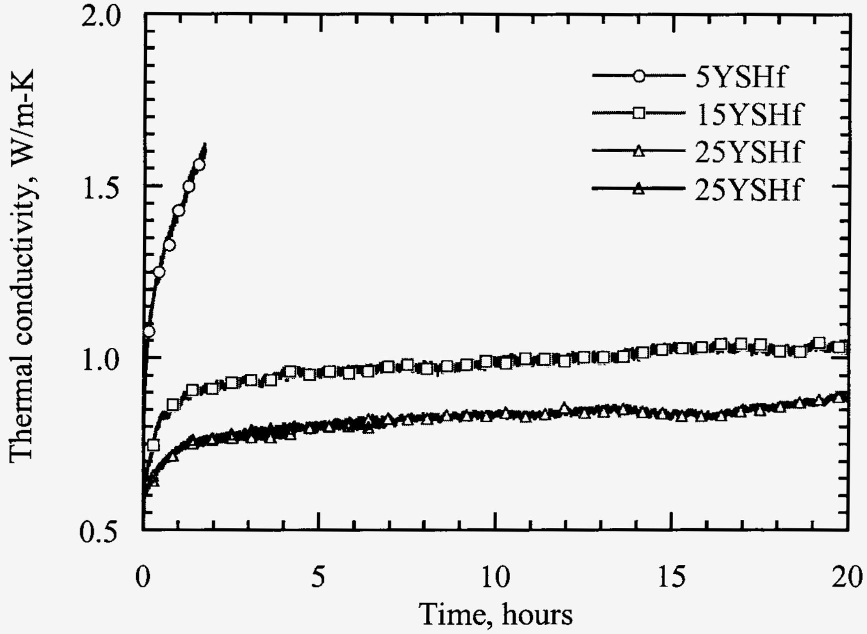
— **Thermal conductivity of $LaMgAl_{11}O_{19}$, $SmMgAl_{11}O_{19}$ and $GdMgAl_{11}O_{19}$**
— **The Gd_2O_3 and Yb_2O_3 co-doped oxides showed the lowest conductivity**

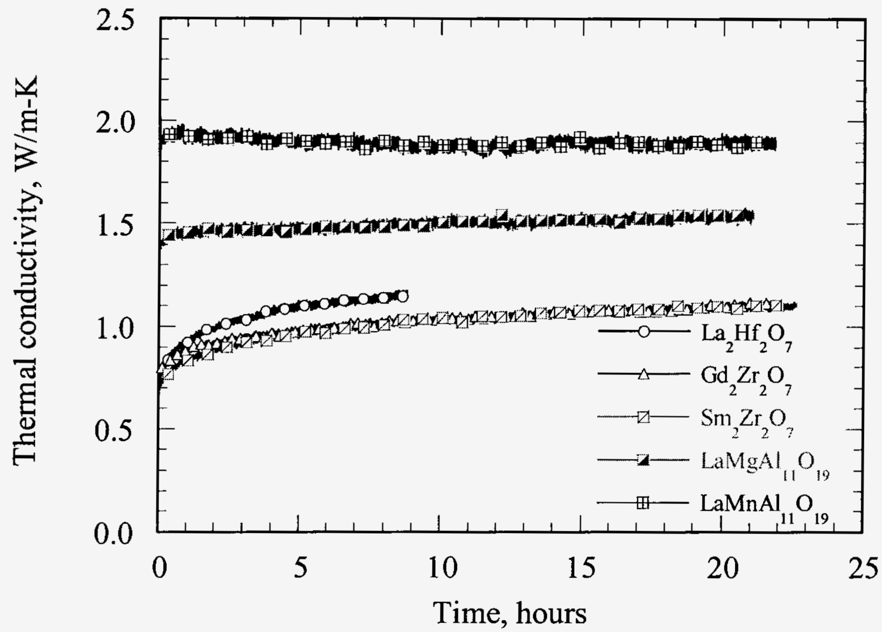




Thermal Conductivity of Advanced Oxide Coatings

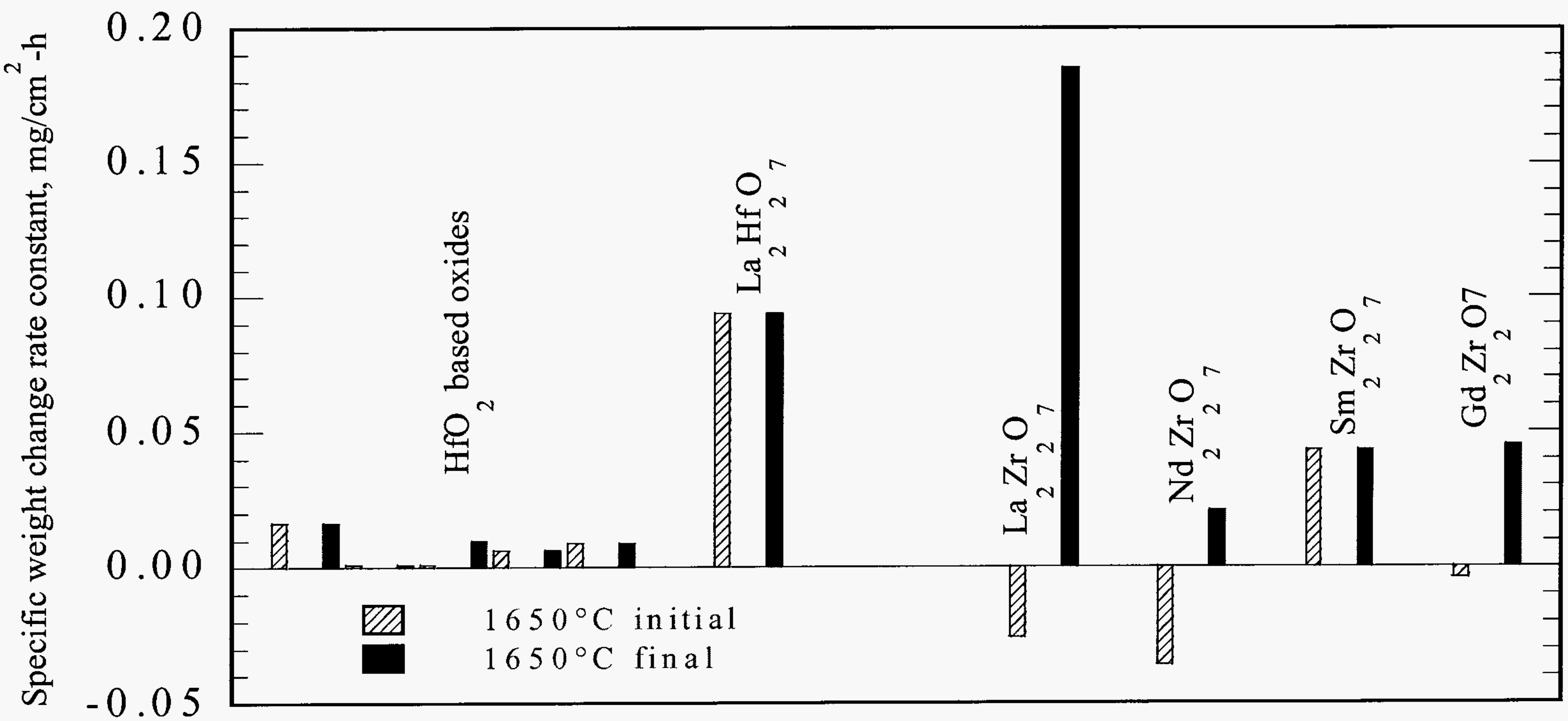
— **Thermal conductivity of plasma-sprayed HfO_2-Y_2O_3, zirconate/hafnate and magnetoplumbite coatings tested at 1650°C**





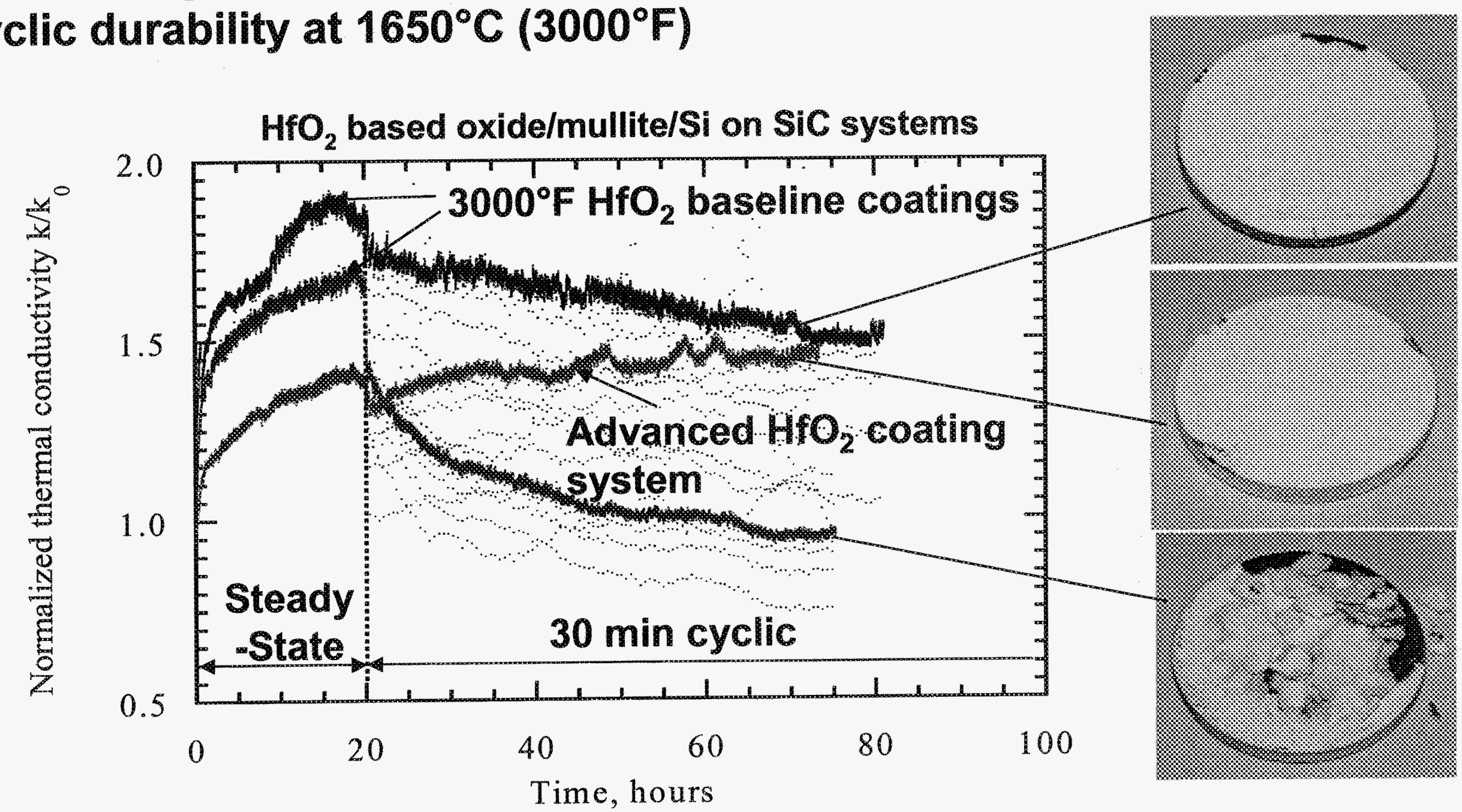
The Water Vapor Stability of Selected HfO_2- and Pyrochlore Oxides

— The water vapor stability of selected HfO2-based oxides and pyrochlore oxides, determined by the TGA tests in a 50-50% flowing water vapor-oxygen environment at 1650°C.



Advanced 3000°F (1649°C) Coatings Development for SiC/SiC Combustor Liner and Vane Applications

- Mutli-component hafnia- and perovskite-oxide-based coating systems being developed and radiation barrier incorporated
- Low stress, advance strain tolerant interlayer and EBC concepts established and demonstrated
- The coating systems demonstrated up to 120 hot hour sintering and cyclic durability at 1650°C (3000°F)



Concluding Remarks

- Advanced HfO_2, pyrochlore and magnetoplumbite oxides are being developed for 3000°F thermal/environmental barrier coating applications

- Rare earth doping and composition optimization have demonstrated an effective approach for reducing thermal conductivity, and improving thermal and water vapor stability.

- Mullticomponent, co-doped oxide systems generally showed better performance.

- HfO_2 and certain pyrochlore oxides are promising candidate materials for the 1650°C (3000°F) coatings because of their low thermal conductivity and high temperature stability in oxidizing and water-vapor containing combustion environments.

- Further studies are needed to investigate magnetoplumbite materials for the high temperature coating applications.

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